

Indicator: Extent of Coral Reef Cover (210)

It is generally acknowledged that coral reef ecosystems are increasingly threatened on a global scale due to a variety of factors including runoff of nutrients, sediments, and pollutants; changes in water temperature and clarity; as well as effects of the fishing industry (Gardner et al., 2003, 2005). Reefs serve an important ecological function by serving as nursery, habitat, and feed areas for many marine species. As such, coral reefs are often hotspots of marine biodiversity (Gardner et al., 2005). Recent assessments suggest that a significant fraction (10-16%) of the historical extent of coral reef coverage worldwide has been lost with a like fraction severely damaged (Wilkinson, 2000). There is a wealth of small-scale quantitative studies currently available for synthesis covering the US section of the Caribbean basin over the last 20 to 30 years. Given the lack of long-term monitoring studies, meta-analysis of these independent studies provides the best window into the status and trends US Caribbean coral reef ecosystems during the recent past.

A total of 79 independent studies representing the years 1973 to 2002 were examined for this analysis. The areas covered are the US Virgin Islands, Gulf of Mexico, Puerto Rico, the Florida continental coast, and the Florida Keys. The data points presented are mean hard coral cover values from individual studies. The data were collected in one of two ways: 1) transect data or 2) quadrat data. Thus, each data point consists of a mean, sample size, and some error measure (standard deviation or standard error) based on replicated transects or quadrats at a particular point in time and space. Error estimates are not presented here.

What the Data Show

In Figure 1, data combined from the Caribbean studies reveal a variable, but highly significant decline in overall percent hard coral cover over time ($P < 0.001$). The mean percent of hard coral cover dropped from 60% in 1973 to just over 20% in 2002.

Indicator Limitations

- Because this indicator represents a meta-analysis of other studies, the temporal and spatial coverage of the data is somewhat heterogeneous.
- This indicator covers only coral reefs in the U.S. section of the Atlantic Caribbean basin and therefore represents only a small portion of the world's total coral reef cover.

Data Sources

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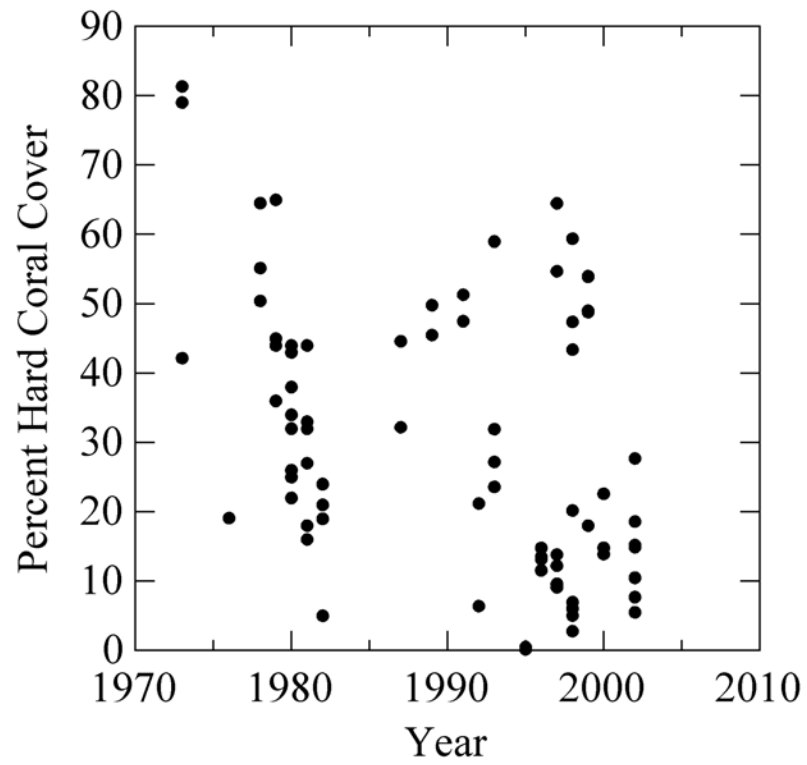
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Graphics

Figure 1

Caribbean Hard Coral Cover, 1973-2002



R.O.E. Indicator QA/QC

Data Set Name: EXTENT OF CORAL REEF COVER

Indicator Number: 210 (89505)

Data Set Source: Multiple independent studies

Data Collection Date: Irregular: ca. 1970-present

Data Collection Frequency: Roughly yearly

Data Set Description: Percent Hard Coral Cover

Primary ROE Question: What are the trends in the extent and distribution of the Nation's ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. The methods are a subset of those used by Gardner and colleagues (2003) and developed by Rosenberg, Adams, and Gurevitch (2000). Gardner, T., I. Cote, J. Gill, A. Grant, and A. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301: 958-960. Rosenberg, M., D. Adams, and J. Gurevitch (2000). MetaWin: Statistical Software for Meta-Analysis. Version 2. Sinauer Associates, Sunderland, MA.

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. The metadata uses standard transect and quadrat coral field sampling techniques. Gardner, T., I. Cote, J. Gill, A. Grant, and A. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301: 958-960.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Yes. The data are direct measurements. The analyses are well-established. Gardner, T., I. Cote, J. Gill, A. Grant, and A. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301: 958-960. Gurevitch, J., and L. Hedges (1999). Statistical issues in meta-analyses. *Ecology*. 80: 1142-1149.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

The indicator speaks directly to the extent of one of the Nations important ecosystems that provide habitat for a wide range of coastal marine species. The sampling designs are appropriate for the individual studies. The data are metadata, and as such, are not from a single monitoring program. Although there is data from several monitoring programs. Also, being metadata, they are not homogeneous with respect to sample size, averaging

time, etc. The central data set covering the Caribbean contains 79 data records. These are mean percent hard coral cover data for the US Caribbean region. They are brought together from a multitude of studies but all contain sample size and variance data.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems? Because of threats from pollution, water warming, and a number of other issues, the entire Caribbean region can be classified as a sensitive ecosystem with regard to hard coral cover.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment? There are no established reference points for what constitutes a desirable threshold for the extent of coral reefs, but the relatively long time series available from metadata allows a solid trend to be established.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used? The list of references compiled for the metadata. See the indicator text document; the list is too long to fit here.

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

The complete data set is available both as Excel and Systat files. (Thomas Forbes: forbes.thomas@epa.gov, 202-566-0810.)

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. Only complete and sufficient designs were selected for the database. In this case, complete means that 1) there was a standard method of collection (quadrat or transect) and 2) a mean, N, and error was included. A reference for QA in Meta-analysis is: Gurevich, J., Curtis, P.S., and M.H. Jones. 2001. Meta-analysis in ecology. *Adv. Ecol. Res.* 32: 199-247.

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

The procedures for sampling and data collection are completely accessible in the assembled literature for the metadata (available from Thomas Forbes: forbes.thomas@epa.gov, 202-566-0810). Procedures for the meta analysis can be found in: Gardner, T., I. Cote, J. Gill, A. Grant, and A. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301: 958-960. Gurevitch, J., and L. Hedges (1999). Statistical issues in meta-analyses. *Ecology*. 80: 1142-1149. Rosenberg, M., D.

Adams, and J. Gurevitch (2000). MetaWin: Statistical Software for Meta-Analysis. Version 2. Sinauer Associates, Sunderland, MA.

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Yes. See: Gardner, T., I. Cote, J. Gill, A. Grant, and A. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301: 958-960. Gurevitch, J., and L. Hedges (1999). Statistical issues in meta-analyses. *Ecology*. 80: 1142-1149. Rosenberg, M., D. Adams, and J. Gurevitch (2000). MetaWin: Statistical Software for Meta-Analysis. Version 2. Sinauer Associates, Sunderland, MA.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes. All metadata consists of sample size, mean, and error values. Contact: Thomas Forbes, forbes.thomas@epa.gov, 202-566-0810, for a list of references.

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Sources of error and potential biases are those of all ecological meta analyses. For a comprehensive discussion, see: Gardner, T., I. Cote, J. Gill, A. Grant, and A. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301: 958-960. Gurevitch, J., and L. Hedges (1999). Statistical issues in meta-analyses. *Ecology*. 80: 1142-1149. Rosenberg, M., D. Adams, and J. Gurevitch (2000). MetaWin: Statistical Software for Meta-Analysis. Version 2. Sinauer Associates, Sunderland, MA.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?
No. The limitation (no long term, consistent, monitoring data) was handled with meta analysis.